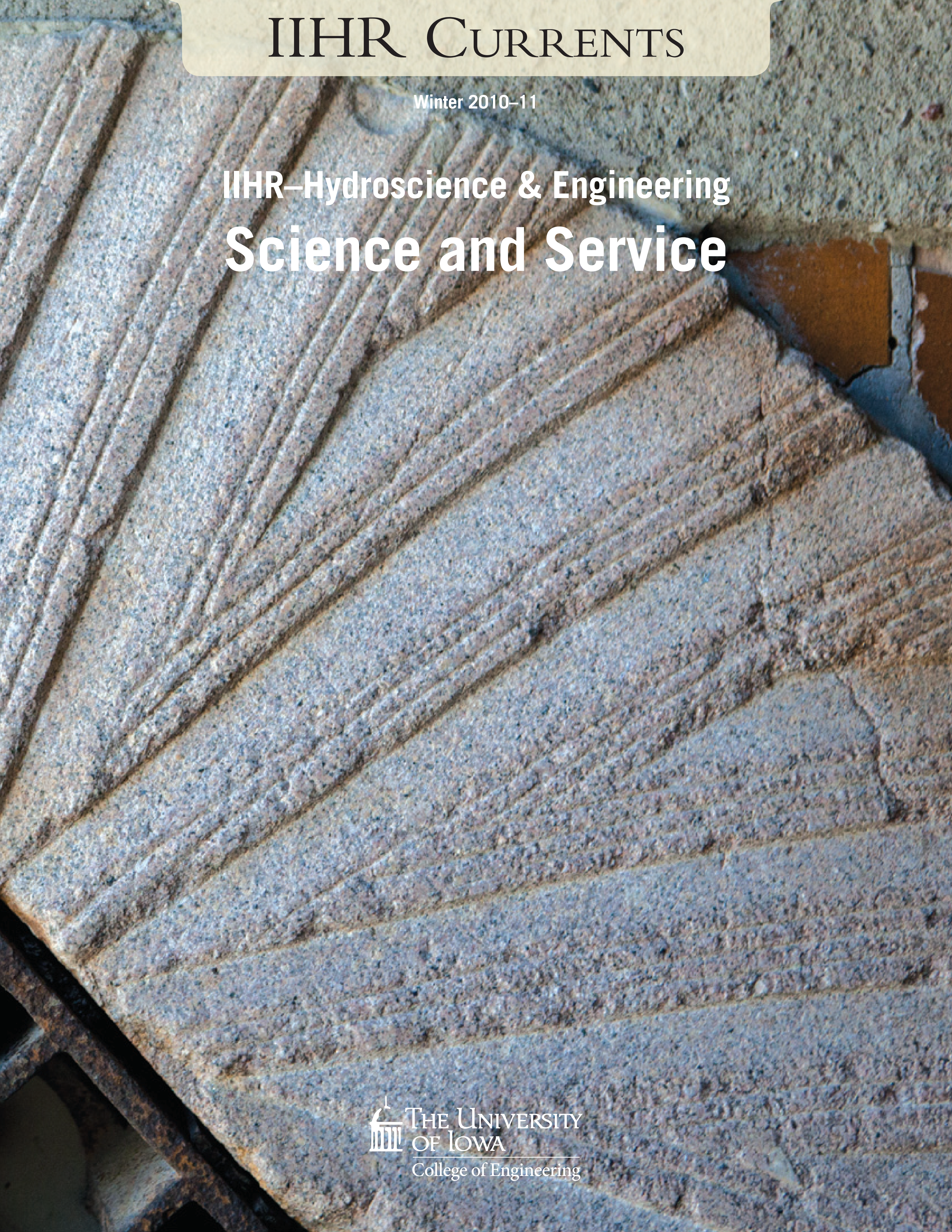
IIHR Currents

Winter 2010–11

IIHR–Hydroscience & Engineering

Science and Service



The University of Iowa
College of Engineering

Contents

IIHR—Hydroscience & Engineering

Mission Statement

To be a leader in fluids-related fundamental and applied research; to provide interdisciplinary education for future leaders in science and engineering; and to advance knowledge in support of sustainable natural and engineered systems.

Vision

To be an international leader among academic institutions in hydroscience and engineering research recognized for integrating laboratory, field- and simulation-based experimentation, and participatory interdisciplinary education.

Editor/writer: Jacqueline Hartling Stolze
Design: Benson & Hepker Design
Photography: Jim Heemstra, except where noted

On the Cover:
IIHR's first director, Floyd Nagler, collected millstones like this one, which has greeted generations of visitors to IIHR just inside the west-facing door.

Greetings!

It is my pleasure to welcome you to the first issue of *IIHR Currents*. We created this publication to share some of the compelling stories of education, research, and service at IIHR—stories that too often go untold. We'll take you behind the scenes and immerse you in the exciting processes of innovation and education here. Although we can tell just a few of these stories, we hope it will give you a sense of the outstanding work that goes on under the auspices of IIHR.

More than ever, IIHR—Hydroscience & Engineering is focused on service. Our researchers are addressing important challenges for Iowa and the world—and providing a safer, more sustainable future for us all.

IIHR emerged from the flood of 2008 a stronger, more focused institute, with new challenges and new ideas to help us fulfill our mission: to be a leader in fluids-related research, to provide a meaningful education to our students, and to advance knowledge in our core areas of sustainable natural and engineered systems. We spent nearly a year crafting our new mission statement to help define the IIHR of the future (see sidebar on the previous page for the text of our mission and vision statements).

As director of IIHR, I am learning firsthand that the challenges of leading a 90-year-old institute are many. As befits a leader in scientific innovation, IIHR is constantly re-inventing itself to stay current and relevant. Now more than ever, it is important that we remain a prominent center for education, research, and service.

One of the most dramatic developments after the 2008 flood was the creation of the Iowa Flood Center (IFC)—an excellent example of how education, research, and service can work together. IFC Director Witold Krajewski speaks often about the importance of "living with floods." Helping Iowans learn to live with floods is just one of the ways the IFC and IIHR are serving the citizens of Iowa—with information, technology, and education, to help mitigate future damage and suffering caused by flooding.

You can read more about the flood center in these pages, as well as feature stories on several other major IIHR research efforts that serve the public in diverse ways, including:

- Study of PCBs and other toxins in the Great Lakes;
- Phytoremediation research, which uses poplar trees and other plants to break down toxic substances in the environment;
- Safe and efficient fish passageways through hydroelectric dams;
- The unique fluid mechanics of the human circulatory system, and the refinement of mechanical heart valves; and
- New developments in ship hydrodynamics and computational fluid dynamics.

I hope this whets your appetite to learn more. To view a video about IIHR produced for "Iowa Magazine," visit **www.youtube.com** and search for "IIHR." We're also in the process of a major redesign of our website (**www.iihr.uiowa.edu**). We would love to hear your feedback on these efforts to better tell the stories of IIHR. Send your thoughts to me at **larry-weber@uiowa.edu**.

Larry J. Weber
Director, IIHR—Hydroscience & Engineering
Professor, University of Iowa Department of Civil and Environmental Engineering
Edwin B. Green Chair in Hydraulics

Iowa Flood Center

Living with Floods

Like it or not, Iowans are learning to live with floods. How will we cope with with this new reality?

Many questions need to be answered. How can we build our communities to live with this reality? How can we mitigate damage to homes, businesses, and the environment from future floods? How can new technologies help?

The Iowa Flood Center is working to find the answers.

After the Flood

In 2008, floodwaters inflicted millions of dollars in damage to The University of Iowa campus. Even as the waters rose, UI researchers were studying the flood and gathering time-sensitive data. This research was the genesis of the Iowa Flood Center (IFC), the nation's first academic center devoted to the study of floods.

The IFC was founded in 2009 with first-year state appropriations of $1.3 million to support the center's overarching objective of improved flood monitoring and prediction capabilities in Iowa.

Through collaborations with communities, individuals, government agencies, and decision-makers, the IFC is bringing engineering and scientific expertise to flood-related issues. These new partnerships and priorities, forged across boundaries and viewpoints, are one of the most hopeful outcomes of the 2008 flood, says IFC Director Witold Krajewski.

IFC research depends on the 20 or so talented students who collaborate with faculty and researchers. From both The University of Iowa and Iowa State University, these students receive hands-on training and expertise that spans a variety of academic disciplines, preparing them for the complex problems of the 21st century.

Renewed state funding and other grants are allowing the IFC to continue advancing our understanding of floods. In November 2010, a new $10 million grant to the IFC from the U.S. Department of Housing and Urban Development was announced, to fund projects that help Iowa minimize erosion, manage runoff, and mitigate future flood damage.

Krajewski, who is an IIHR research engineer and professor of civil and environmental engineering, says the center is a vital resource for Iowans as they prepare for future floods.

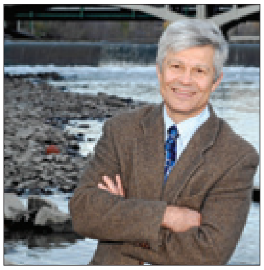
Current IFC Research Initiatives

Where Does the Water Come From?

Runoff from heavy rainstorms will always find its way downstream, impacting communities many miles away. An understanding of the river basins in which we live can help Iowans know what's coming, and when.

The IFC is in the process of calculating basin boundaries using recently updated digital elevation models of the state. The maps are available with a user-friendly interface on the IFC website.

Next steps in this initiative, already underway, include overlaying NEXRAD-derived rainfall data, stream gauge information, and estimated flood travel times on the maps. With this knowledge, officials will make better choices to improve water quality and manage storm runoff.



Collaborations and Partnerships

The IFC brings together numerous partners and collaborators, and by working together, these groups collectively provide a better service to Iowans:

- Iowa Department of Natural Resources
- Iowa State University
- National Weather Service
- National Oceanic and Atmospheric Administration, National Resources Conservation Services
- U.S. Army Corps of Engineers, Rock Island District
- Communities around the state

PHOTOS BY ANETA GOSKA

Forecasting Floodwaters

In 2008, runoff from several different storms upstream arrived in Cedar Rapids at the same time, pushing water levels to disastrous levels. This "water traffic jam" can be compared to the effect of heavy rush hour traffic on a city's streets.

Understanding the water traffic jam is important to improve flood forecasting. Combined with up-to-the-minute precipitation data and river level information gathered by stream stage sensors (see below), forecasters will have new tools to use to keep Iowans informed of a changing flood scenario.

Affordable Stream Stage Monitoring

Until recently, gauges to measure river and stream levels were few and far between in Iowa. IFC students helped develop an affordable electronic sensor to measure stream levels and transmit up-to-the-minute data to the center. The sensor is usually placed on the downstream side of bridges and uses sonar to measure the distance from the water's surface to the sensor. This information, transmitted via cell phone to a central database, provides an accurate picture of current stream levels.

The Iowa Department of Natural Resources (DNR) and IFC recently completed a pilot project to deploy a preliminary network of 50 sensors across the state. A statewide system that could be in place within a few years would enhance the ability to monitor stream stages and predict flooding.

Web-Based Flood Inundation Maps

IFC researchers are developing high-resolution web-based flood inundation maps for several communities in Iowa. With data gathered through bathymetric surveys to determine the shape of the channel, supplemented by aerial LiDAR data, researchers can create very detailed maps of the streambed, which can be used to illustrate the extent of flooding under different conditions.

The information is available to the public via an interactive Google Maps-based online application (www.iowafloodcenter.org/maps), so homeowners, business owners, and others can see how predicted flood levels could affect their property and make informed decisions.

For more information, visit www.iowafloodcenter.org.

Opposite: IFC Director Witold Krajewski.

Below: Three of IIHR's four new mobile X-band radars were set up west of Iowa City in late 2010 for testing and calibration. The set of four radars, optimized for rainfall observations, will operate as a network for data quality control and improved estimation of rainfall intensities. The radars will help the Iowa Flood Center develop improved algorithms for estimating precipitation from radar data.

PCBs

The Thrill of the Hunt

For more than a hundred years, toxins generated by heavy industry in East Chicago, Indiana, settled to the bottom of the Indiana Harbor and Ship Canal (IHSC), creating a deep layer of thick sludgy mud that is home to everything from heavy metals to polychlorinated biphenyls (PCBs).

The Army Corps of Engineers has announced plans to dredge the canal in the next several years for navigational reasons. The plan raises serious questions for researchers at The University of Iowa. When dredging stirs up a century's worth of toxins, especially PCBs, what will happen? Will it be better or worse for the people and the environment nearby?

IIHR—Hydroscience & Engineering researchers hope to answer those questions and others through a project within the Iowa Superfund Basic Research Program (ISBRP). ISBRP is a large initiative that brings together projects at several institutions to study the sources, transport, and fate of PCBs. ISBRP is funded by the National Institutes of Environmental Health Sciences.

PCBs are known to be dangerous to people and the environment, says Keri Hornbuckle, IIHR research engineer and UI professor of civil and environmental engineering. Hornbuckle is also associate dean for academic programs for the College of Engineering. She is co-lead researcher of an ISBRP project that focuses on the sources of PCBs. Other IIHR researchers involved in ISBRP include Jerry Schnoor (leader, phytoremediation) and Craig Just (leader, community engagement — see sidebar at right).

"The toxicity is really pretty clear, although not totally understood," Hornbuckle says. "It's one of the most toxic chemicals out there, and it was produced in huge magnitude. So the National Institutes of Health are very interested, for good reason."

Hornbuckle says the canal already presents a tragic situation. "It's the largest tributary release of PCBs into Lake Michigan, other than the Fox River," she says. "It's got every industrial hazardous chemical you could possible imagine … It's just a mess. It would be good to reduce this source of toxic chemicals to Lake Michigan."

Researchers are concerned that the plan to dredge the canal could stir up high levels of PCBs buried in the sludge and release them into the air and water, with potentially dangerous effects to people and the environment. Hazardous as these toxins are at the bottom of the canal, Hornbuckle says, it is unclear if removing the sediments will improve the situation.

Hornbuckle's research has focused on the Great Lakes, although she notes that PCBs have been found worldwide. "We're really concerned about these chemicals in the Great Lakes, because they accumulate in fish," she says. Fortunately, she says, interest and funding for Great Lakes research are plentiful. "There is a community of people who demand it," Hornbuckle says. "[The Great Lakes are] an amazing freshwater resource."

Hornbuckle and her team of students have been working in the Chicago area, measuring PCBs in the air, water, and soil to find the sources and quantify the levels and movement of the compounds. The team used tandem mass spectrometry to measure PCBs in the canal sediments, an analytical technique that allows researchers to better identify the original sources and future fate. "We have found that the concentration of PCBs in the sediment increases with depth," Hornbuckle says. "So if they're not thinking at all about PCBs, and they simply dredge off a meter in depth, they're going to expose really high concentrations."

Andres Martinez, one of Hornbuckle's postdoctoral scholars, quantified the levels of PCBs being released from sediments in the canal, even before any dredging has occurred. The results demonstrate that even under quiet conditions, sediment in the canal is a significant source of PCBs to the air and water. Other sites with similarly high levels of PCBs have been declared Superfund sites, which by law must undergo clean-up.

The researchers don't delve into the politics of a tricky situation like the dredging of IHSC, Hornbuckle says. They simply do their work and disseminate their findings, helping others make better informed decisions. In this case, however, one of Hornbuckle's former graduate students, David Wethington, serves as the Army Corps of Engineers manager for the dredging project. As a student, his work focused on the release of PCBs in Milwaukee. Knowing that someone so well-informed on the subject of PCBs is in charge makes Hornbuckle hopeful.

"He understands the story completely with respect to PCBs," she says. "It's a very complicated situation. I could never have prepared him for what he does now. But I hope I've helped!"

The work continues to inspire Hornbuckle's passion for serving the public good, which she in turn passes on to more students every year. It's no problem motivating the students, Hornbuckle says. "We're really lucky to get to do this kind of work. It makes it easier to work hard on it, when you think it really matters."

And, she adds with a smile, "It's really fun."

PHOTO BY TIM SCHOON/UNIVERSITY RELATIONS

IIHR Research Engineer Keri Hornbuckle aboard the EPA research vessel *Lake Guardian*. In September, she took students on a research expedition on Lake Michigan near Chicago to collect air and water samples.

Knowledge is Power

It's difficult to make an informed decision without the facts.

The dissemination of information is part of the mandate for any Superfund Basic Research Program, which must benefit the community in which the work is done.

IIHR Associate Research Scientist Craig Just is the Iowa Superfund Basic Research Program leader for community engagement. Just, who is also adjunct associate professor in the Department of Civil and Environmental Engineering at The University of Iowa, helps coordinate and deliver community education opportunities in the schools and through other community organizations in East Chicago, Indiana, and in Columbus Junction, Iowa.

"We also work with Community Advisory Boards in each community to help us understand the broader issues communities are faced with beyond the study of PCBs," Just explains. "Our presence empowers the communities by giving them access to research information that has been translated to lay terms that might help them decide on how they want dredging projects to move forward in the future.

"People need help deciding which things pose the biggest risk to the health of their families, so they can make smart choices to minimize risk," Just says. "Overall, East Chicago is pleasant, but the specific area of our study is heavily industrialized; people are living in close proximity to steel plants, oil refineries, etc. The PCB threat is probably small compared to other things they experience over the long-term, in small doses, every day."

ISBRP research has empowered decision-makers in these communities at all levels, Just says. "Decision-makers did two community health risk assessments as part of this study using 'standard' data that many times does not consider airborne exposures of PCBs," he says. "That's the 'hook' of our research in many ways. We're studying the more volatile of the 209 different PCBs to see how airborne (versus food-borne essentially) exposures rank.

Just says that Hornbuckle's work has already indicated that the exposure threat from the dredging operations is small relative to other things people could be doing — such as eating any fish from the canal.

The Power of Poplars:

Prevailing over PCBs

Green technology is more than a catchphrase for Jerry Schnoor. He and his research team are using the greenest of technologies—poplar trees and other plants—to break down some of the most toxic substances in the environment.

"I think the reason it's so promising is because it is truly a green technology that's low cost and natural," Schnoor says. "It's the type of technology people would like to see."

Schnoor is a research engineer associated with IIHR—Hydroscience & Engineering, as well as the Allen S. Henry Chair in Engineering in the UI College of Engineering. His work in phytoremediation—the use of plants to clean contaminated soils—is part of the Iowa Superfund Basic Research Program, which focuses on the sources, transport, and fate of polychlorinated biphenyls (PCBs).

PCBs are known to be among the most toxic chemicals in existence, and they are difficult to clean up. "They're very persistent—for decades," Schnoor explains. That's one reason why his work in phytoremediation is so groundbreaking. "We were the first ones to discover that plants can actually degrade PCBs," Schnoor says.

Dredging of the Indiana Harbor and Ship Canal in East Chicago, Indiana, has stirred up controversy due to the high levels of PCBs and other contaminants in the canal's sediments (see story page 4). A proposed Confined Disposal Facility (CDF) in East Chicago would provide a site for the dredged materials, and researchers hypothesize that poplar trees, planted in or around the CDF, could help mitigate further release of PCBs.

The hybrid poplar tree is among the plants most commonly used in phytoremediation. "There's a good reason for that," Schnoor explains. "It's a plant that grows very quickly and roots very deeply, and uses a lot of water. … Secondly, it's a model plant from a molecular biology standpoint. We have the complete genome."

This in-depth knowledge of the genome makes the poplar ideal for determining exactly what is going on in the phytoremediation process, Schnoor explains. "Exactly how does it work?" he asks. "What's the molecular biology? What's the biochemical machinery that is allowing these degradation reactions to occur? What is the gene that encodes for the enzyme that's actually degrading the chemical?"

Originally, researchers thought bacteria in the root zone were degrading the PCBs. The IIHR team has learned that there's more going on. "We've shown that the plant material itself can transform PCBs," Schnoor says. "That was a nice contribution."

Plenty of work remains. One of the research goals is to prove that phytoremediation can break down PCBs to innocuous end products, such as carbon dioxide and water. Currently, the toxicity of metabolites produced after phytoremediation is still uncertain. "It's possible that some of them are as toxic, or even more toxic, than the original," Schnoor says. "We're continuing to follow that story. But in general, it's thought that it's on the pathway to breaking them down."

Schnoor and his team have completed several successful site clean-ups. Their longest-running work was at a former petroleum tank farm in West Virginia. The leaky tanks contaminated soils and a nearby creek. Schnoor and his team planted poplar trees at the site in 1999, which have now grown to maturity. The site is densely vegetated, and the oil has been substantially removed. A recent scientific paper published in the journal *Water Environment Research* documents the improvement in soil and groundwater. According to the abstract, the concentration of benzene, toluene, ethylbenzene, xylene, and gasoline range organics (GRO) decreased an average of 81 percent, 90 percent, 67 percent, 78 percent, and 82 percent, respectively, in the lower soil horizons, and 34 percent, 84 percent, 12 percent, 19 percent, and 59 percent, respectively, in groundwater.

It's a gratifying success for Schnoor and his students, and helps keep them motivated to continue working. "We really enjoy what we're doing, and feel like we're able to make a positive difference in the world," Schnoor says.

Student Sam Bircher agrees. "It's an honor to be working on an interdisciplinary team as talented and as dedicated as our phytoremediation group," he says. "I'm also thrilled to be a part of a research project that is really … 'doing good' for our planet."

IIHR Research Engineer Jerry Schnoor, center, examines samples of the hybrid poplar with student members of his research team: (l to r) Alexandra Beebe, Sam Bircher, Guangshu Zhai, and Richard Meggo.

Think Like a Fish

IIHR Engineers Make Hydroelectric Dams More Fish-Friendly

The tricky part of designing a safe passage for fish through a major dam is learning to think like a fish.

Getting fish safely past major hydroelectric dams has been an issue since the early 20th century. Fish ladders worked well for passage upstream, but engineers and biologists were initially surprised when the dams also had a big impact on fish moving downstream. When fish passed through the turbines, rapid pressure changes left them stressed and susceptible to waiting predators.

Ever since, engineers have been working on better ways to get fish safely past the dams. IIHR researchers have been involved in fish passage research since the 1930s, and working with the Grant County Public Utility District (PUD) in the Pacific Northwest for more than 30 years.

Larry Weber, now director of IIHR, was part of a team of IIHR engineers trying to analyze data tracking fish movements near a major hydroelectric dam in the mid-1990s. The information was gathered with multi-beam hydroacoustics—a high-tech version of the fish-finders many sport fishermen use. The researchers saw that some of the fish were swimming right up to the dam and then retreating.

"That's the smoking gun, right? Why are those fish leaving?" Weber asks. The IIHR engineers were confident they could overlay the trajectories of the fish onto computer-generated flow fields to see what conditions the fish were responding to.

"We figured, 'We're smart, we're engineers, and we can do that,'" Weber remembers.

What they found, however, was less than illuminating. "The results of that were, 'Holy cow, we can't make heads or tails out of any of this,'" Weber says.

A breakthrough came soon after when Weber met John Nestler, a fisheries biologist (now retired) with the U.S. Army Corps of Engineers. They realized their work had followed similar paths, but Nestler had focused primarily on the fish's perspective. "He knew way more about fish biology, fish sensory systems, and what exactly fish can sense and monitor—what a fish might like hydrodynamically," Weber says.

What if they worked together, with the engineers concentrating on developing hydrodynamic models, while Nestler focused on analyzing fish behavior? That's exactly what they did, with funding from the U.S. Corps of Engineers. The IIHR team provided Nestler with flow data developed using computational fluid dynamics (CFD), while Nestler analyzed how fish responded to the flow.

Nestler and his colleague Andy Goodwin went beyond that to develop a computer model to help researchers understand how fish would move in a particular flow environment. For instance, a fish usually swims nose first when it's in a low-energy flow field and actively trying to reach the ocean. "When the energy level in the flow gets high, or the velocity gets higher, it turns around and swims tail-first," Weber explains. "If it gets bad enough that they want to escape, they're pointed in the [right] direction."

The team took the research a step further by placing acoustic tags on hundreds of fish and releasing them upstream from the dam. The tags sent out a 'ping' picked up by hydrophones strategically placed in the reservoir. Using this new acoustic data, researchers could accurately triangulate the positions of the fish and learn more about their behavior near the dam.

Researchers found that fish swimming up to a guide wall, even at night, would track along it until they sensed a change in the flow they didn't like. "They couldn't see it," Weber says. "They were responding to the flow field. So, now we're like, 'Oh, this is interesting.'"

They also noticed that the fish seemed to dislike rapid acceleration in the flow. “The fish sense that acceleration and they’re avoiding it,” he explains. “They’re going in tail-first, and thinking, ‘Oh, this isn’t right.’ And they get the hell out of there.”

After retreating, the fish mill around and may go up to the dam to test the waters again. “We have records of fish going up and trying this four or five times,” Weber says. Some fish eventually choose to go through the turbines instead.

Why would fish pass through the turbines rather than through the fish passage structure? Apparently, Weber says, they prefer the smoothness of the flow acceleration up to the turbine. According to Nestler, what matters is the hydrodynamic environment a fish experiences as it’s moving along.

Andy Goodwin wrote algorithms that reflected this new knowledge. Their resulting computer model (known as the Numerical Fish Surrogate) was an important breakthrough. “It’s the only model of its kind,” Weber explains. “Other people have tried, quite unsuccessfully. We continue to apply it at a number of different dams.” These insights led to new fish passage designs with flared entrances to make the flow accelerations more gradual.

As important as the Numerical Fish Surrogate is, Weber says, it needs to be accompanied by good engineering judgment, good biological judgment, careful laboratory and numerical simulations, and more. “The cautionary point is, it’s not the only tool in our toolbox,” Weber says.

The National Marine Fishery Service sets fish passage survival goals for dams on the Snake and Columbia rivers in the Pacific Northwest. The IIHR team was able to predict the success of fish passage designs with remarkable accuracy, better serving clients such as Grant County PUD. The fish passage system now in use at the Wanapum Dam in Washington State was developed using this combination of scientific tools and methods. It has helped the utility achieve a 95 percent survival rate for fish passing the dam.

The fish passage system at Wanapum cost the utility $52 million to build, but Weber says it is exceeding all performance expectations biologically.

There is still plenty of room for new developments and improvements in fish passage, Weber says, and he credits IIHR’s success to the many team members who have contributed to the efforts over the years. “It’s still very interesting to me,” he says. “The blend of success for our industrial partners and the accomplishments scientifically has been outstanding.”

Members of IIHR’s fish passage research group in the 1/64-scale Priest Rapids tailrace model. Pictured are: (front) IIHR Director Larry Weber; (second row, l to r) Director of Engineering Services Troy Lyons and Associate Research Engineer Marcela Politano; (back row, l to r) graduate students Ali Reza Firoozfar and Antonio Arenas Amado, Staff Engineer Andy Craig, and Assistant Research Engineer Justin Garvin.

The Heart

The first mechanical heart valve looked like a small ball trapped in a cage. "It worked pretty well," says IIHR Research Engineer K.B. Chandran, holding the valve up for inspection.

Chandran has a collection of heart valves, gathered during his 30-plus years of study in biomedical engineering. He is dedicated to understanding the unique fluid mechanics of the human circulatory system, and the dynamics of heart valves. Chandran is the Battershell Chair Professor of Biomedical and Mechanical Engineering and former chair of biomedical engineering at The University of Iowa.

Mechanical heart valves have evolved a lot since the ball and cage days.

"The next advancement in valve design was called the tilting disc valve," Chandran says, holding up another valve. "This is still on the market." He points out the valve's single leaflet, which opens and closes, simulating the action of a natural valve.

"The most recent valve design is called the bi-leaflet valve," he continues. "The whole thing is made of pyrolytic carbon. That material is chemically inert, so it doesn't deteriorate in the body, or cause any caustic effects."

Chandran and his team have contributed a great deal to this continuing evolution. It's a complex area of study, he says, that continues to fascinate and challenge him. One of the complicating factors is blood itself, which doesn't behave like most fluids. As anyone who has ever had a cut knows, blood clots to prevent blood loss. On the other hand, a clot, or thrombus, can form around a mechanical heart valve of any type and cause problems, and for this reason patients who receive the valves must take an anti-coagulant for the rest of their lives. Chandran wants to know why the thrombus forms, and how it could be prevented.

So what makes blood unique among fluids? "Forty-five percent by volume of blood is blood cells, like red blood cells, white blood cells, and platelets," Chandran explains. "We cannot just look at blood as a simple fluid. We have to study the interaction of the red blood cells and platelets as blood flows past a mechanical valve to determine why the clots form."

of the Matter

The human circulatory system adds another layer of complication. Flow past a heart valve includes constant interaction between flowing blood and the moving leaflets, so simulations must involve the development of a fluid-structure interaction analysis. Variations in anatomy and other factors often play a role. “That creates a lot of challenges in the development of this fluid-structure algorithm,” Chandran says. “It’s much more complicated than normal engineering flow problems.”

Biomedical engineers use computer simulations (known as computational fluid dynamics, or CFD) to predict the flow field around a mechanical valve, but again, blood complicates things. “In a small 1-mm cube of blood, there are millions of red blood cells,” Chandran explains. “Currently the computer cannot handle computing all that.”

So engineers are developing multi-scale analysis, which begins by performing the simulation at the large scale, and then zooms in to see the detailed mechanics within a small region of a heart valve or blood vessel. In this case, scale is the complicating factor. The disparate range of scales varies from extremely small (e.g., blood cells, which are microns in size) to the relatively large (e.g., the heart itself, which is the size of a human fist – approximately 100,000 times bigger than a blood cell). In addition to the CFD work, Chandran and his team also perform a variety of experiments dealing with flow around a mechanical heart valve. As an example, using micro-PIV (micron resolution particle image velocimetry), Chandran’s team is able to measure fluid and blood cell dynamics in a microscopic flow. The results from the experimental work can then be used as a benchmark to validate the CFD simulations.

But the simulations are still more than any one computer — even a super computer — can process. Chandran says that multi-scale simulations are one way to address such problems. For such large-scale computations, they are also using a cluster of more than 200 computers. The software “delegates” part of the computation to each processor. The computers do the work simultaneously, much faster than a single computer could. “That’s called parallelizing the computation,” Chandran says. “As technology develops and we get more understanding, we can get better and better simulations.”

The computer simulations have many applications. Chandran and his team are working to help cardiologists understand why some patients born with a defect of the aortic valve get along fine, while others develop problems. “We are trying to find out which of these patients are at risk and why, from a mechanical point of view,” Chandran explains.

Another project involves the mitral valve; when it doesn’t function correctly, surgery is often required to correct the problem. Again, CFD can help. “We are trying to use our simulations to see the best way to repair that, from a mechanical point of view.”

For Chandran, this is what makes the work rewarding: the opportunity to improve the quality of life for others. “Hopefully this kind of analysis will bear fruit,” he says. “It’s a problem close to my heart.”

Far left: IIHR Research Engineer K.B. Chandran (second from left) and his team focus on the fluid dynamics of mechanical heart valves. Pictured are: (l to r) Assistant Research Engineer Sarah Vigmostad, Chandran, Associate Research Engineer H.S. Udaykumar, and graduate students Vijay Govindarajan and Paul Jermihov.

Left: Mechanical heart valves have evolved tremendously since the ball and cage valve (right) was introduced.

Safer Ships

Through IIHR Simulation-Ba

PHOTOS BY MIKE SCHLOTTERBACK/FISHEYE PHOTOGRAPHY

IIHR—Hydroscience & Engineering at The University of Iowa is leading a revolution in naval ship design.

No longer must the navy "build and test" its ships — with real sailors aboard, risking their lives — to find out how vessels will perform under real-life conditions. Researchers at IIHR are using simulation-based design (SBD) — a sort of virtual reality of ship hydrodynamics, supported by model-scale experiments — to develop a safer, less expensive way to design modern high-performance naval vessels.

"In my thinking, this is going to revolutionize engineering," says Professor Fred Stern, IIHR research engineer and director of ship hydrodynamics, in a video produced for the Big Ten Network. "Engineering will become more and more based on simulation techniques as time evolves."

Under Stern's leadership, researchers at IIHR have developed a groundbreaking computer code, CFDSHIP-Iowa, simulating air and water flow around a virtual ship. CFDSHIP-Iowa is the most advanced computational fluid dynamic (CFD) computer code in the world for ship hydrodynamics, allowing researchers to predict the performance of a virtual ship prototype under extreme environmental conditions.

Computer simulations at IIHR guide model-scale physical experiments conducted in a towing tank and in a new state-of-the-art wave basin at the UI Research Park (see sidebar). The experiments, on the other hand, help evaluate the limitations of current mathematical models and allow researchers to develop better models. With uncertainty analysis and optimization methods, researchers are able to develop the best possible design, Stern explains.

UI engineering students, in particular, benefit from this revolution in engineering. Graduate students have been the co-developers of CFDSHIP-Iowa since its genesis in the early 1990s. Undergraduates also participate, Stern says. "We need to ensure that they're highly-trained, expert users of tools such as computational fluid dynamics," he explains. A recent National Science Foundation project introduced computational fluid

SED DESIGN

dynamics into the introductory and intermediate level fluid dynamics courses at The University of Iowa as well as Iowa State, Cornell University, and Howard University.

Stern believes this is crucial to a 21st century engineering education. “My thinking very much is that our students need to be exposed to and use simulation technology and computer technology from the get-go,” he says.

IIHR’s unique combination of resources, facilities, and people promises an ongoing role for The University of Iowa in the front lines of naval ship design, Stern says. “We’ve contributed in all areas, I would say, very strongly—not only the development of codes, the procurement of experimental data, but also the application of the codes.”

“There’s still plenty of work for us to do,” Stern concludes.

Left: Graduate students Seong Mo Yeon (left) and Bonguk Koo prepare one of the model-scale ships for use at IIHR’s new wave basin.

Below, top: IIHR Research Engineer Fred Stern.

Below, bottom: Closeup of the overhead carriage that tracks model ships through the water at IIHR’s new wave basin.

IIHR Wave Basin Supports Research

Most of us remember playing with toy boats in the bathtub as children. Believe it or not, we probably learned a few things about how water and ships interact through those early “experiments.”

IIHR’s new $4.9 million wave basin facility takes that concept to an entirely new level. Research engineers use the 40x20x3-meter wave basin to test captive or radio-controlled model-scale navy ships under a variety of real-life conditions, created by the basin’s six wavemakers. The free-moving models can maneuver just like real ships — straight ahead, zigzag, full circle, and even capsize.

The wave basin allows measurement of local flow around a free-running model — something that’s never been done before, says Professor of Mechanical and Industrial Engineering Fred Stern.

“It’s a very innovative design,” he explains. “I think that we have a key role that we’ve been playing for the navy, and will continue to play, in terms of developing the cutting-edge computational methods,” Stern says.

A custom eight-ton overhead carriage tracks the radio-controlled ships using indoor global positioning and two-camera vision, shadowing the vessels to within +/-100 mm. A 3D particle image velocimetry system will measure fluid velocities around the ships, facilitating the collection of detailed flow data. The model-scale ships can be tested for maneuvering, seakeeping, capsize, and more — potentially saving lives when the ship design is in use by the U.S. Navy.

IIHR’s wave basin is the first to include local flow measurement capabilities, critical for continued development of SBD tools. Unlike towing tanks using captive ship models, which typically allow only straight line movement with very limited side to side motion, the wave basin facility with its local flow measurement instruments can test ships under many different real-world conditions, measuring the water flow and wave patterns around the ship, including breaking waves, bubbly ship wake flows, unsteady hull surface pressure, and more.

The new wave basin at IIHR will help the U.S. Navy meet the challenges of the 21st century by supporting and validating the data gathered through computer simulations.

PHOTO BY MIRANDA MEYER, UI CMP PHOTO SERVICES

Learning from the River: IIHR Offers Water Quality Class

Fishing with electricity can earn you a hefty fine in Iowa, but it's a valuable tool when used by scientists and fishery management teams to gauge the health of a stream. Students in the University of Iowa Water Quality class offered by IIHR got the chance to try electrofishing for themselves earlier this year.

This hands-on class is taught out of LACMRERS (the Lucille A. Carver Mississippi Riverside Environmental Research Station), IIHR's Mississippi River field station near Muscatine, Iowa. Class work is combined with field work, so students get to experience some of what they study.

Collaborators from government agencies and other organizations are an important part of the class. Mike Schueller is the supervisor of limnology (the study of surface water, and the characteristics and processes of aquatic systems and their watersheds) with the UI State Hygienic Laboratory. Schueller has helped LACMRERS Director Doug Schnoebelen teach the class several times. Fish can provide a lot of useful water quality information, Schueller says. "Fish are … consumed by humans," he says. "So we're always interested."

After an hour in the classroom at LACMRERS, Schueller took the students to nearby Pine Creek. Wearing a backpack electrofisher unit, Schueller instructed the students on the finer points of netting fish. It's not as easy as it looks!

Walking three abreast with the students, Schueller lowered the device into the water, where it emits a low pulse of electric current. Students netted the stunned fish and put them in a plastic bucket of stream water. After the fish are identified and analyzed, they're released back into the stream unharmed.

Later, the UI students dug for mussels in the shallows of the Mississippi River, where they saw firsthand the invasive zebra mussels that are choking out Iowa's native species, such as Higgins Eye.

"It's been fun getting out on the river," says Adam Nielsen, a graduate student at IIHR. Sean Murphy, also an engineering graduate student, agrees. "It's a nice change of pace to actually do some of what we talk about," Murphy says.

Doug Schnoebelen shares their enthusiasm. "This is the next generation that's going to doing something about water quality," he says. "It's good to get them excited about the river!"

PHOTOS BY JACQUELINE HARTLING STOLZE/IIHR

Top: In June 2010, students in the Water Quality class sampled the water at Pine Creek at Wildcat Den State Park.

Bottom left: Mussels from the Mississippi River.

Bottom right: IIHR graduate students Adam Nielsen (left) and Tom Smith at Wildcat Den State Park.

Water World: IIHR Takes Students 'Where the Action Is'

These days, more and more college students spend at least one semester studying abroad, and many consider it an essential part of their education for future careers in an increasingly globalized world.

For engineering students, however, it can be difficult to find the time. Students who do study abroad often have to delay graduation. Graduate students in the midst of complicated research can't set aside their work for a semester of study abroad.

Yet no one can deny that engineers must deal with global challenges, defined less by borders than by watersheds.

IIHR has a solution: International Perspectives in Water Resource Science and Management (IPWRSM), a two-week study abroad course, offers students the chance to experience another culture firsthand, while focusing on water resource issues from a variety of perspectives. Students prepare for the course and settle on a project topic before they leave Iowa. After their return, they complete the project and share the results in seminars and presentations. The course is usually offered during winter break (January) or between the spring and summer semesters (May).

International Perspectives packs a lot of content into a short course, says organizer Marian Muste. Muste is an IIHR research engineer and adjunct UI professor of civil and environmental engineering. "In two weeks, we had 35 invited speakers, eight site visits, three lab visits, seven sightseeing visits, and 11 presentations given by our group," he says about the 2010 trip. "They were jam-packed days."

The course now benefits from the help and resources of The University of Iowa's International Programs. Muste says the assistance has been invaluable. "Working with International Programs, we learned much more from their experience, and we started using more and more of their resources."

First developed by then-IIHR Director V.C. Patel in 1997, the course is still unique, Muste says. "The idea of the course was to take students 'where the action is' in water resources. We look for world highlights in the area. That's how we took the students in 2003 to the largest dam in the world, in Argentina. Then when the Three Gorges was built in China, we went to China."

The 2010 trip continued the tradition of going "where the action is." "We targeted The Netherlands and United Kingdom as the pioneers of a new concept in flood mitigation — living with floods — and being the best in implementing it in the world," Muste says.

In the Netherlands, flood mitigation is an absolute necessity, says IIHR graduate student and course participant Maria Perez. "Half of their country would be underwater if it wasn't for the flood control structures," she says. "Everything is so controlled."

Students in London (l to r: Taryn Tigges, Maureen Coat, and Fabienne Bertrand) try out the Abbey Road street crossing made famous by the Beatles.

Sam Boland, also an IIHR graduate student and course participant, agrees. "Almost their whole country is engineered, which is kind of cool."

Muste believes it's important to see firsthand how other countries cope with water-related problems. "Field trips are very important," he explains. "But [especially] field trips with international dimensions, with multi-faceted dimensions, with real people talking."

The conversation is not limited to engineers — participants come from across the academic spectrum. "We have people from urban planning, from geography, from law, and from history, [all] talking about water issues," Muste says. "And of course, engineers."

The mix is important, he says, because when water problems occur, they must be jointly solved by individuals from many perspectives. For students, he says, it's a critical part of the learning process to begin having these conversations now.

Cultural exchange is another enjoyable component of the course, Muste says, and students agree. "You learn so much," Perez says. "Not just about the engineering work, but you also have fun and learn about other countries."

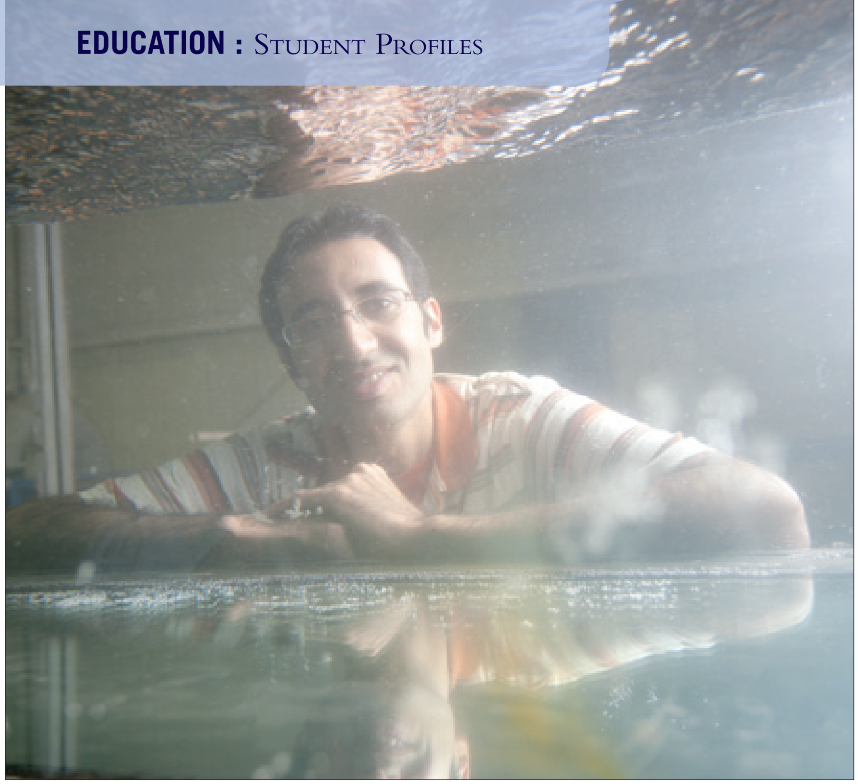
Muste says a strong group dynamic develops quickly. "This team spirit develops very nicely," Muste explains. "They take care of each other."

Perez concurs. She was in the early stages of pregnancy during the trip to The Netherlands and the U.K., and she says her fellow students made sure she was doing OK—especially Boland. "He took care of me," she says.

Friendships develop on the trip differently than at home. "That was a highlight for me," Perez says. "To get to know the people who we go to class with or see all the time, but we never get to know. On the trip, you really get to know who they are."

The next iteration of International Perspectives will take students to India and Bangladesh in late December 2011 and January 2012. Muste is already hard at work organizing the trip. "That region is very flood-prone," Muste says. "You will find in one place areas which are completely in their natural state in terms of fighting floods, and then very modern systems of warning and monitoring.

"We see with our eyes these kinds of good or bad things," he says. "We look for both."



Running Down a Dream

Even when Seyed Mohammad Hajimirzaie ("Haji") was a child living in Iran, it was clear he had a future in water engineering. For instance, on vacation near the Caspian Sea, young Haji would leave the house early in the morning while his parents were still asleep to rescue fish and other sea creatures stranded in tidal pools. So it's no surprise that when he came to IIHR for a PhD, Haji would have liked to work in fish passage, designing systems to help fish safely pass dams and other manmade structures.

Although Haji is now focusing on mussel habitat in Mississippi River rather than fish passage, he still feels he is pursuing his dream.

Haji works with faculty member James Buchholz; their work examines the hydrodynamics of flow around small aspect ratio obstacles, such as mussels. Their work is motivated by the need for a better understanding of transport mechanisms in fresh water mussel populations. "Flow structures around small aspect ratio obstacles have been an issue for almost 60 years," Haji says.

"Right now, I'm doing experiments in the flume with cylinders and a semi-ellipsoidal physical model that is geometrically similar to a mussel," Haji says. The team has identified a base vortex in the mussel's wake, which no one had seen before with an obstacle this small.

Haji's flume study uses particle image velocimetry (PIV), an experimental technique, to measure velocity fields in the flow around the mussel. "It's really interesting," he says. "Before this I never thought that the flow structure around small things, like mussels, could be important, or so very complicated."

But even though the mussel research is on a small scale, its potential applications are vast. "Our work can be expanded to very different engineering applications — control surfaces on aircraft and underwater vehicles, sails, and cowlings on submarines; components on electronic circuit boards; buildings and exhaust stacks; and boulders, clusters, and fish habitat structures on riverbeds. It's quite interdisciplinary," Haji explains.

He hopes someday to follow the example of his mentors at IIHR. "Teaching is my desire, always," Haji says. "It's a very dynamic job."

He also hopes to someday return to Iran, where he knows his knowledge will be useful. "Water has always been an issue in my country."

Serendipity Happens

Sometimes, life happens when you're making other plans. Liza Shrestha, a master's student in biomedical engineering, says her career in engineering almost seemed to choose her.

"I wanted to be a chartered accountant!" the Nepal native recalls.

Shrestha's excellent exam scores carried her to one of Nepal's best universities, and like many other bright students in her country, Shrestha chose to study science. And later, she was accepted to the engineering college.

"Everything just happened," she says. "I thought, OK, so this is what I was supposed to do."

And she has discovered that she likes it, especially fluid mechanics. "Since Nepal has a really good potential in water supplies — it's called the second largest country in water resources — I wanted to work in that field," she says.

Serendipity played a role, too, in bringing Shrestha to IIHR and The University of Iowa. She searched for a university in Europe, but wasn't able to find adequate financial aid. "Complete funding was not possible from my parents," she says. "So I kept on looking."

And found IIHR. Here, Shrestha is working in the area of biomedical engineering, specifically blood flow in coronary arteries. Again, it was not in her original plans. "My professor said, 'It's just a change in viscosity. Would you be interested?' And I just thought, 'Well, it's flow. It's everything related to fluid mechanics. And I'd be doing CFD stuff. So why not?"

Shrestha works with Assistant Professor of Biomedical Engineering Sarah Vigmostad. Shrestha studies atherosclerosis — the narrowing of the arteries due to deposits of cholesterol. She runs computer simulations to look for areas of low or oscillating wall shear stress that are generally the regions of high accumulations of cholesterol materials.

It's easy to stay motivated, Shrestha says, and she is glad she chose engineering. "Engineering is a direct application of science," she explains. "I feel that I'm doing something really important for people."

Troubled Waters: IIHR Researchers Study Oil's Effects on Coastal Plants

In the summer of 2010, UI researchers found a hostile environment on the Gulf Coast — and not just because of the BP oil spill.

"We couldn't take the boat where we wanted to, because the Coast Guard had authority," says Jerry Schnoor, a professor of civil and environmental engineering. "We couldn't get to some of the more heavily oiled sites."

Schnoor's students, Elliott Beenk and Aaron Gwinnup, traveled to the Gulf Coast to study the oil's effect on the Gulf marshlands, and to determine the potential for native marsh grasses to perform phytoremediation (the use of plants to break down toxins, such as petroleum).

Gwinnup and Beenk traveled to the Gulf Coast in June, when oil was still gushing out of the disabled Deepwater Horizon. The well was damaged on April 20 when an explosion killed 11 workers and began the worst offshore oil spill in U.S. history. They were able to collect clean samples of the Gulf's sediments and native marsh grasses near Grand Isle, Louisiana, and bring them back to the laboratory at The University of Iowa for further study. With the help of co-researchers at Louisiana State University, they eventually received samples of oiled marsh grasses and sediments, as well as a sample of crude oil polluting the gulf.

Back in Iowa City, the team's work is progressing in the lab, where they are simulating the spill by adding oil in varying amounts to beakers containing the sediment and native salt marsh plant samples. They hope to learn how the plants react to oil, how much they can tolerate, and how quickly they can recover.

Beenk says that the overarching goal of the research is to study how phytoremediation could help restore the marshlands if they die. He and Gwinnup hope their research can help produce some good out of a bad situation. "The oil spill, while a terrible occurrence, provided a large-scale natural experiment on the effect of crude oil on threatened salt marshes in the Gulf Coast," Gwinnup says.

Since the well has been capped, authorities have reported that the gulf is recovering more quickly than expected from the environmental disaster. Gwinnup has his doubts. "Certainly the gulf contains a healthy population of microbes that are proficient at metabolizing oil and its constituent chemicals," he says.

"I am, however, very concerned about the chemical dispersants used," Gwinnup says. "Research has shown that the dispersants are more toxic than the oil itself, and the microbes in the gulf have evolved to proficiently deal with oil, not dispersant, and not oil mixed with dispersant. … It is possible that the dispersants could dramatically increase the time it takes nature to break down the oil, if they create large, deep-water hypoxic plumes of neutrally buoyant oil."

Graduate students Aaron Gwinnup (left) and Elliott Beenk examine samples of the marsh grass they brought back from the Gulf Coast.

Student Awards and Recognition

- **Ken Wacha**—Graduate Assistance in Areas of National Need Fellowships (GAANN) (PhD; adviser, T. Papanicolaou)
- **Jeremy Bril**—Graduate Assistance in Areas of National Need Fellowships (GAANN); named national director of education and projects, Engineers for a Sustainable World; Outstanding Student Paper Award, American Geophysical Union (AGU) (PhD; adviser, C. Just)
- **Shane Cook**—2009–10 Richard B. Stewart Thermal Fluids Scholarship (MS; adviser, Fred Stern)
- **Achilleas Tsakiris**—Paul C. and Sarah Jane Benedict Award for Study of Alluvial River Processes; Best Poster Award, College of Engineering Research Open House; selected to receive funding from the UI Graduate College Strategic Initiative Fund (PhD; adviser, T. Papanicolaou)
- **Justin Hannon**—2010–11 Hydro Fellowship, Hydro Research Foundation (MS; advisers, Larry Weber and Justin Garvin)

Engineers Without Borders: Service with a Smile

Adiza, a 15-year-old girl living in a small rural village in Ghana, had stepped on a nail.

"Her foot was beyond swollen," says Sara Rourke, a University of Iowa medical student. "I've never seen a foot that swollen before."

Sara and her husband, Nathan Rourke, are members of the University's student chapter of Engineers Without Borders USA (EWB). In June 2010, the couple traveled to Kobriti, Ghana, with a team of UI students and faculty advisor Craig Just, an IIHR associate research scientist, to begin a five-year EWB service project there. Adiza was just one of the many children they got to know in Kobriti.

"Her skin had started to peel away, and she just looked really sick," Sara says. Adiza also had a fungal infection on her head that had caused her hair to fall out.

"Every 15-year-old should have hair," Sara says firmly.

Sara convinced Adiza's family that the girl needed care at the district hospital in Ejura, about 10 miles away. "We got her a tetanus shot," Sara recalls. "We got her some antibiotic, and I dressed her wounds at the hospital."

And then it was time for lunch. Adiza was shy at first, but once she abandoned the unfamiliar silverware and ate with her hands, her appetite took over. "She must have eaten three times as much as I did," Sara laughs.

A Multi-Disciplinary Team

It was a good day, one of many for the UI students in Ghana. The team included a medical student (Sara) and an international studies major (Kali Feiereisel), two engineering students (Nathan and Thomas Bang), and Just. The team spent five weeks in Ghana last summer.

Just, who is also an adjunct associate professor of civil and environmental engineering, thinks the student diversity enhances the group's effectiveness. "I'm convinced it's the perfect arrangement," he says.

Engineering projects for the village take time, Just explains, but the medical student can hit the ground running. "When you announce there's a med student around, people will bring their sick children," he says.

The students surveyed the village to learn about demographics, employment, water sources and storage, and health concerns. Water turned out to be a major concern. "That's all they would say, over and over," Just says. "'We need better access to water.'"

Do No Harm

Future engineering projects for Kobriti will likely address water quantity and storage first, perhaps followed by sanitation, Nathan says. The Ghanaians will be involved at every stage. "EWB has had a lot of success that way, in keeping projects sustainable by keeping the communities involved, so they have the ownership in the project," Nathan says.

The community's water supply comes from two bore holes. "The wells tested bacteria-free," Nathan says, but water quantity is a problem, and water storage raises new issues. The stored water likely would not be safe to drink untreated. "We've got to be very careful," Nathan says. "It's the issue of 'do no harm.'

"If we feel like they're going to be drinking it straight out of the tank, it's probably really important to look into point-of-use sanitation," he adds. The chapter will weigh issues like these as it considers upcoming engineering projects for Kobriti — but the final decisions will be made with the villagers.

"That's the most important thing," Just says. "They're ultimately their projects, and we're there to assist."

PHOTOS COURTESY OF SARA AND NATHAN ROURKE

Top: UI medical student Sara Rourke examines a Ghannian woman in June 2010.

Middle: Children pump water in Kobriti.

Bottom: UI student Thomas Bang with a young Ghanaian friend.

Rock Star Treatment

Sara often spent half-days working at the hospital in Ejura, work that sometimes left her feeling overwhelmed. “I knew I could help if I had the right equipment and diagnostic tools and medications,” she says. “They have so little. That was the frustrating part.”

Returning to the village after a shift at the hospital was like coming home, she says. “The people there were amazing,” Sara says. She and Nathan became especially attached to the children. “They don’t really speak your language, but they would try,” she says. “They would call us ‘Obruni’ because that means white person. They would say, ‘Obruni, Obruni, how are you?’ They only understand one response, which is, ‘I am fine. How are you?’ Then they’d giggle and run away.”

Children in Ghana work hard. “These kids, they’re tough as nails,” Sara says. “After a trip like this, you come back and you don’t whine about anything.”

Nathan and Sara say they felt like celebrities in Kobriti. Children and adults alike would greet them with huge smiles and waves. “‘You are my friend,’ they would tell you,” Sara recalls. “‘You are my friend.’”

Nathan says it was hard to return to the United States and give up that special status. “It was a reality check to get back here and nobody cared,” he laughs.

Sara agrees. “We were used to being able to say hi and get a response like we were rock stars.”

Sara and Nathan will both graduate in May 2011. But that doesn’t mean they’ve forgotten Kobriti. They hope to return to Ghana, and they want to make service projects like this a part of their professional careers.

Sara gets regular e-mail updates from Ghana courtesy of Benjamin Kusi of Self-Help International, an Iowa-based NGO partnering with the UI EWB chapter.

“Last week he sent me an e-mail with a couple pictures of some little girls I was really worried about,” Sara says. “They’re doing a lot better. I haven’t quite let go yet.”

She adds, “I don’t think I’m going to.”

Learning to Live … Sustainably

Living in the dorms is an education in itself. Meeting new people from all over—and learning to live with them—is one of the bonuses of a college education.

The University of Iowa is expanding the residential experience with its Living-Learning Communities, a program designed to help first-year students make the adjustment to college life, while also building a support network among people with like interests.

IIHR Associate Research Scientist Craig Just is the liaison for the UI’s Sustainability Living-Learning Community (SLLC). Just is also the College of Engineering’s coordinator for sustainability programs.

SLLC advisor Craig Just (second from left) talks with students on a beautiful fall day. Pictured are: (l to r) graduate assistant Emily Gorsalitz, Just, resident assistant Nicole Larson, and residents Lexie Swift, Austin Bell, Christina Achrazoglou, Kahli Kastella, and Hollyanne Butler.

The SLLC, now in its first year, is part of an expanding program at the UI. “The goal is to have all students who live in the residence halls be part of a Living-Learning Community,” Just says.

It makes sense, Just explains, when you consider the University’s mission to educate students. “We’re not in the apartment business, we’re in the learning and teaching business. So if you’re going to be on our campus, living here, there should be some kind of learning outcome tied to your residence experience.”

The University sponsors more than a dozen Living-Learning Communities. Two popular examples have an engineering focus: Men in Engineering, and Women in Science and Engineering. The new Sustainability Living-Learning Community, however, is a bit harder to define.

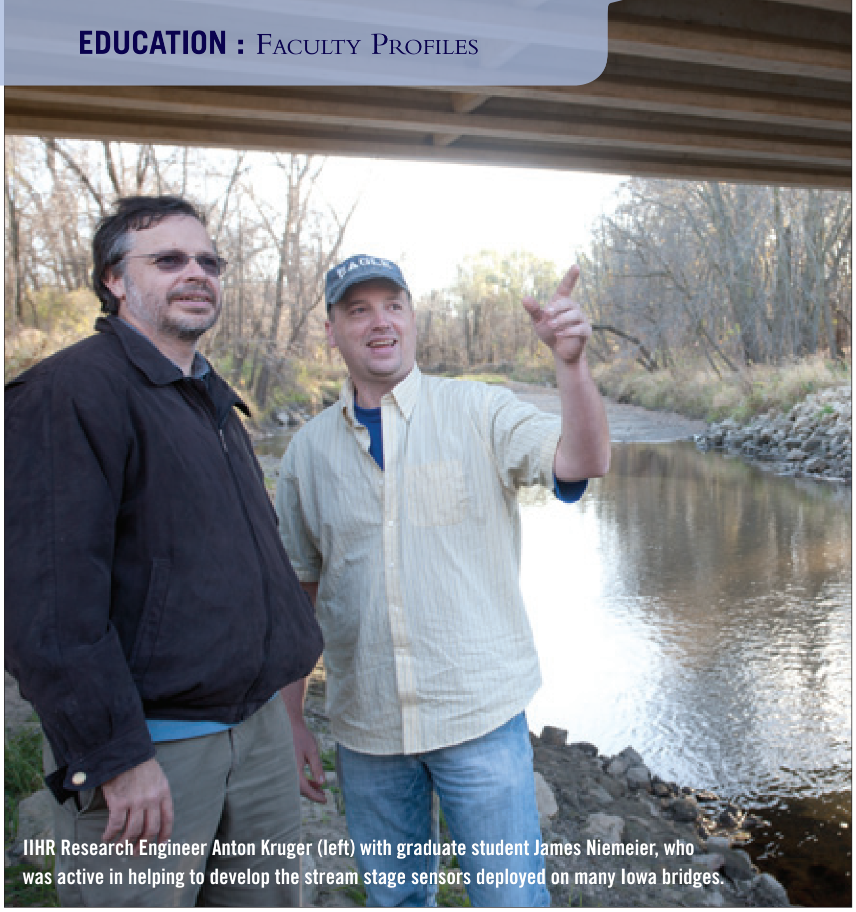
“When you say sustainability, hardly anyone can define what the heck that is, let alone identify your major with sustainability,” Just says. “That’s been the major challenge so far.”

Sustainability isn’t limited to engineers—in fact, Just says, the program is very interdisciplinary, and students bring a variety of majors and viewpoints to the SLLC. Programming reflects that diversity.

In fall 2010, students learned about urban gardening; they visited MacBride Nature Center to visit the raptor center and go canoeing; and they attended a lecture by environmentalist Bill McKibben. In the spring, students will be involved in the student garden, and they hope to develop recycling and composting projects.

“There are some great people in the SLLC—really active and excited to get things going,” says Kahli Kastella. She is a journalism major and hopes to pursue a certificate in sustainability. Kastella is one of about 25 active SLLC members living in Mayflower Residence Hall.

Resident assistant Nikki Larson, an environmental engineering major, says no one is running around shutting off lights or scolding people for long hot showers. “Sustainability in general is an individual choice,” she says. “You can be educated on what could help, and then weigh the options yourself.”



IIHR Research Engineer Anton Kruger (left) with graduate student James Niemeier, who was active in helping to develop the stream stage sensors deployed on many Iowa bridges.

How Stuff Works

As a boy, Anton Kruger couldn't resist dismantling his toys to find out how they worked.

"Nothing was safe when I was around," he admits. "My mom used to buy us these little wind-up toys. It wasn't 10 minutes before I would open them and break them to see all the gears and such."

Kruger still likes to find out how things work. "I sometimes feel like a nerd," he says. "The same stuff that interested me as a kid, still interests me. I love engineering. I just want to know how this stuff works."

A native of South Africa, Kruger came to The University of Iowa for a PhD in engineering. After completing his degree in 1992, he accepted a position as a programmer at IIHR. Kruger didn't know much about the institute when he took the job. "I would wander the hallways, and I would run into these people, and I would have no idea that they're really famous in their field," he admits. "I was just clueless."

No longer clueless, Kruger is now a research engineer, working primarily with the water and air resources group, but also on instrumentation for a variety of IIHR projects. "For me as an electrical engineer, it's a great vehicle," he says.

About five years ago, Kruger was named a faculty member in the Department of Electrical and Computer Engineering. When asked which aspects of his job interest him most, Kruger responds without hesitation. "To be honest, I enjoy working with the students. That's what I really enjoy."

He believes the students at Iowa are exceptional. "I would have to say they're outstanding—very bright, hardworking. They keep me on my toes."

Kruger gives students the credit for much of what he's achieved at IIHR, including a recent Iowa Flood Center project to develop cost-efficient stream stage sensors installed on Iowa bridges. "Lots of students were involved—it was a big team effort," he says.

All in all, Kruger says, IIHR has been a good home for him. "Folks say water and electricity doesn't mix, but in my case it actually works out pretty well."

At Home on the River

IIHR Assistant Research Engineer Nandita Basu is a lover of nature and the outdoors. "I wanted my research to make a difference in this area," she says. "Environmental engineering seemed the perfect choice."

Basu, an assistant professor of civil and environmental engineering at The University of Iowa, says ecosystem degradation was an area of particular interest for her. A native of India, Basu focuses on the study of sustainable management of water resources. She is especially interested in how it is manifested in developing areas such as Africa and India.

Basu's work is remarkably interdisciplinary, encompassing engineering as well as natural and social sciences. Her overall research goal is to provide strategies for sustainable management of available water resources—strategies that satisfy the food and energy demands of an increasing population, while minimizing the impacts on the natural environment. Her research expertise lies in the fate and transport of contaminants in natural systems.

She says the work continues to fascinate her. It also remains quite challenging because of its complexity and interdisciplinarity. "It's just mind-boggling," Basu says—but that very complexity is part of its appeal.

For Basu, teaching is definitely one of the highlights of her work. "My biggest joy is when the students' faces light up with the 'I got it!' look," she says.

As a woman in engineering, Basu has become accustomed to being a minority in a male-dominated field. "It's a bit challenging always," she says, and admits she sometimes craves the company of other women in her profession. She is a supporter of women's networking groups in engineering, and sees positive progress being made for women in the field.

For Basu, the boundaries between work and pleasure can be a bit fuzzy. "I am very fortunate to be able to enjoy my work," she says. "When I was a kid, I used to love solving puzzles for fun. Now I get paid to solve them."

Although her profession has carried her far from her home in India, Basu says she enjoys her work at IIHR, which continues to challenge and captivate her.

On the Trail of Sediments

"I think maybe I was born at the right time," says Thanos Papanicolaou.

The IIHR research engineer and UI professor of civil and environmental engineering is part of a generation of engineers who have faced unprecedented challenges, requiring new ideas that cross traditional boundaries and expand on the successes (and correct the failures) of the past. His lifelong fascination with water and physics has carried him from his native Greece to the banks of the Iowa River in Iowa City, where his work at IIHR allows him to focus on his passion for water.

Papanicolaou's research focuses on sediments and soil, and how they interact with flow. He and his research team develop methods to predict the rate of transport and deposition of sediment. They can also trace the sediment's source. Radionuclides from rain water adhere to sediments. When the sediments enter streams or estuaries, his team tracks the sediments back to their sources using the radionuclides, Papanicolaou says.

The IIHR team also investigates how agricultural land use practices affect carbon cycle dynamics. "Eventually, what we want is to keep all organic matter, including carbon, in the soil," Papanicolaou says.

One area Papanicolaou finds particularly interesting is the use of bacteria to bond sediments together. The bacteria consume nutrients in the sediment and transform it into a substance similar to stone. Papanicolaou says these "smart sediments" can be useful in a number of situations. For naval purposes, engineers may want to create a stable landing area. Another example can be found in Bremerton, Wash., where contaminated sediments are continually disturbed by passing ferries. Using smart sediments, the problem can be effectively contained, Papanicolaou explains.

This technique is a natural fit for places like the Lower Mississippi River, Papanicolaou says. "The bacteria feed on the nutrients that come from the rivers, so they work very effectively in estuaries."

Papanicolaou is proud of the public service civil engineers provide to society. He cites a culvert design he developed that is now in wide use in the western United States. The culvert facilitates fish passage for juvenile salmon. "Simply said, to allow the small fish to go through," Papanicolaou says.

Another example of public service, particularly to the people of Iowa, centers on the Loess Hills region of western Iowa. The Nishnabotna River develops what engineers call nick points. "The river builds like a staircase, so you have steps forming into the river," Papanicolaou says. "As they propagate, they reach to a bridge crossing, and they get the bridge foundations exposed. That's not good, obviously." Papanicolaou and his team have developed a way to stabilize the nick points, saving bridges and also taking measures to facilitate fish passage.

It's rewarding work, Papanicolaou says. But the best part of his job, he says, is teaching. "I do love working with students," he says. "Actually, that's a big reason why I am in this job."

Papanicolaou is definitely serious about his work—so serious that people may sometimes overlook other aspects of his personality. "I think sometimes I tend to scare people, because I am more quiet and reserved," he says. "But in reality, I am very funny."

Faculty and Staff Awards and Recognition

- **Jerry Schnoor** — Clarke Prize (National Water Research Institute); Simon W. Freese Environmental Engineering Award
- **Witold Krajewski** — 2010 Iowa Board of Regents Award for Faculty Excellence; named Rose and Joseph Summers Chair in Water Resources Engineering
- **Anton Kruger** — UI's James N. Murray Faculty Award; College of Engineering faculty excellence award for teaching
- **Thanos Papanicolaou** — Named Donald W. Bently Faculty Fellow of Engineering
- **Michelle Scherer**— 2010 Malcolm Pirnie/ AEESP Frontier in Research Award; named Robert and Virginia Wheeler Faculty Fellow of Engineering
- **Larry Weber** — College of Engineering faculty excellence award for service; brought in the most research dollars to The University of Iowa in FY 2010 ($15.2M)
- **Nate Young** — Among the top UI researchers with $10.2M in research funding brought in to the University

The Power of Water

For Casey Kramer, a love of the outdoors, and especially the mountain streams in his native state of Washington, pointed him toward his career as a river engineer.

Kramer's enjoyment of the outdoors started early, on backpacking trips with his dad in rural Washington. His love for the steep mountain streams inspired him to study fluid dynamics and sediment transport as an undergraduate engineering student, and to continue those studies in IIHR's master's program.

Kramer's current position as assistant state hydraulics engineer with the Washington State Department of Transportation allows him to help preserve the streams he enjoys. Some of his responsibilities with WSDOT include the bridge scour monitoring program, analysis of riverine systems using various 1D and 2D hydrodynamic and sediment transport models, design of stream bank erosion control and stabilization measures, culvert design, and floodplain analysis.

PHOTO COURTESY CASEY KRAMER

"I'm using a lot of what I worked on as a student," Kramer says. His master's thesis studied the feedback processes between fluid and sediment in a steep mountain stream — similar to those in Washington State. The topographic and hydrologic variety in Washington makes monitoring the scour condition of bridges more challenging and demanding, Kramer says.

Kramer says he's been surprised — and pleased — to discover how much responsibility for public safety resides in his job. "The challenges are what keep the job interesting," he says.

Kramer was part of a student caravan that followed Thanos Papanicolaou, his advisor at Washington State University, to Iowa when Papanicolaou accepted an appointment at IIHR. Moving to Iowa was something that had never occurred to Kramer, and as he and his wife Cindy drove east to Iowa, he began to feel an unfamiliar dampness in the air.

"I had never experienced humidity like that before," he laughs. But he remembers his time at Iowa fondly. "We really enjoyed Iowa City and how friendly the people were," Kramer says. He also developed a dedication to the Hawkeye football team that continues to this day.

His research with Papanicolaou made an important contribution to IIHR, one that's still in use today. "We designed and built the high gradient tilting flume," Kramer says. To complete his work on the interaction of large boulders on flow characteristics, sediment transport, and hyporheic flow in mountain streams, the team acquired two tons of marbles from West Virginia. The clear ones represented the stream bed, and the other colors each represented a different sized sediment particle to assist in quantifying transport rates. "It was really cool," Kramer says.

If he hadn't become an engineer, Kramer says, he might be whipping up some barbecue in his own restaurant. "That's what I miss most about Iowa," Kramer says. He says he still misses Iowa's famous pork tenderloin sandwiches.

But engineering was apparently always in the cards for Kramer. "I always did like taking things apart," he laughs.

These days, he's taking apart and restoring a '73 Ford Bronco he recently acquired. It's a vehicle he's always loved, and Kramer says he's looking forward to using it to explore the mountain wilderness with his family. During the summer, Kramer also spends a good amount of time on local lakes and rivers with his family and friends, either wakeboarding or fishing.

He and wife Cindy have two children, Conner (age 3) and Kayla (4 months). "It's a blast," he says. "Family definitely comes first."

If he was asked to advise a student considering graduate study at IIHR, "I'd definitely say do it," Kramer says. "It will be one of the best decisions you'll ever make."

Iowa Boy

Eric Paterson just might bleed black and gold. The Iowa native is proud of his connections to the Hawkeye State, and in 2010 he added one more when he was named to the IIHR Advisory Board.

As an undergraduate, Paterson came to The University of Iowa to study biomedical engineering. After switching to mechanical engineering, Paterson earned a BSME in 1987. He worked in Florida for several years at Harris Corporation (led by UI College of Engineering Distinguished Alumnus Al Henry) before graduate school drew him back to Iowa. He was the first graduate student to receive the Hunter Rouse Fellowship at IIHR, where he earned MS and PhD degrees. He stayed on at IIHR as a postdoc and later as a research engineer, working on ship hydrodynamics with Fred Stern.

Paterson was one of the original authors of CFDSHIP-Iowa, the most advanced computational fluid dynamics (CFD) computer code in the world for ship hydrodynamics. Paterson says it was exciting to be part of this exceptional team.

In 2001, he was recruited by the Applied Research Lab (ARL) at Penn State, where Paterson is now senior scientist and professor of mechanical engineering. ARL supports more than a thousand researchers and staff, and has long been a major player in research for the Office of Naval Research (ONR).

"When I got here," Paterson says, "90 percent of the funding was from the U.S. Navy." Developing more diverse funding sources soon became a priority, and Paterson diversified, too. His research branched out to include renewable energy from water and wind turbines, heart pumps and cardiovascular flows, and canine olfaction and explosives detection.

The five-year canine olfaction research, supported by ONR and the DARPA RealNose Project, sought to develop a mechanical sniffer to mimic the fluid dynamic principles that had evolved over millions of years in keen-scenting mammals such as dogs and rats. "It was a very ambitious project," Paterson says. "While the complexity of a dog's nose is amazing, it also serves a multi-function role as a cooling and olfaction system, the latter of which packs a large-surface-area sensor into a small volume." While the research group learned many important lessons, Paterson says they still have a long way to go to match the olfactory capabilities of our canine friends.

Paterson has recently returned to ship hydrodynamics with renewed vigor. His work focuses on CFD modeling of submarine and ship wakes, ocean waves and ship response, cavitation, and multi-body interactions. After more than 20 years of involvement with CFD development, Paterson says it is rewarding to see how far the field has come. "When I started CFD," he says, "many people didn't believe we could predict the drag of a ship." Now he finds he sometimes has to temper the enthusiasm for what CFD can do, and make the case for experimental testing. "I wouldn't want to be the engineer who designed expensive and critical systems without some sort of model validation," Paterson says.

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Paterson and his wife Beth have made music for more than 25 years—literally. First, they performed together in the Hawkeye Marching Band, and now in the State College Area Municipal Band. Paterson plays the trumpet, and his wife the bassoon. "It's a wonderful change of pace from the day-to-day pressures of a research career," Paterson says. He also performs in the "Little German Band," a local oompah group that plays at Oktoberfest and other local venues.

Although their kids Ian and Lindsay consider themselves Pennsylvanians, Paterson remains a true Hawkeye. He speaks proudly of the Iowa work ethic, and he makes a point to seek out other Iowans. "I often see Iowans in prominent roles," he says. "It's always nice to see."

PHOTO BY MIKE STENERSON/UI CMP—PHOTO SERVICES

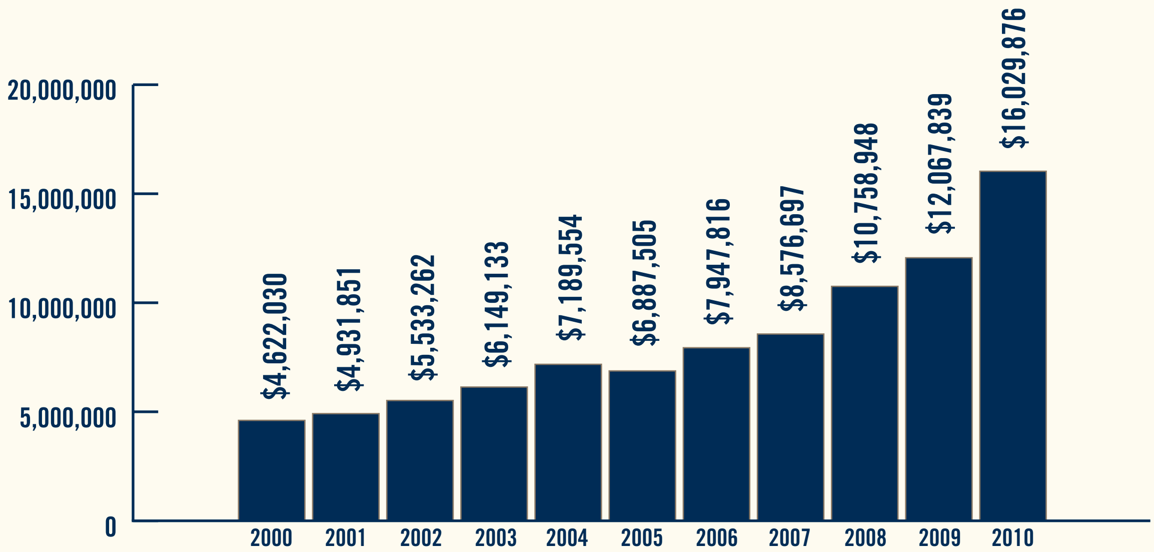
The Fiscal Year In Review

IIHR's rapid growth in recent years can be attributed to several factors, including the development and success of several large multidisciplinary research programs and, most recently, the establishment of the Iowa Flood Center.

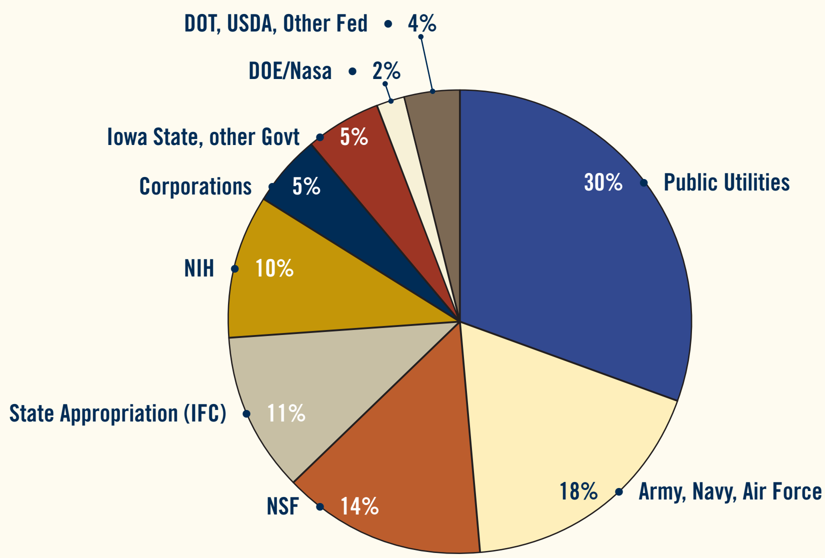
One of IIHR's keys to success is its healthy blend of funding sources. Fiscal year 2010 (July 1, 2009–June 30, 2010), for example, included 35 percent private funds, 49 percent federal funding, and 16 percent state and local support. These numbers have fluctuated over time depending on the economy, the nature of IIHR's current projects, and other factors, but blended together, they provide a stable financial foundation.

IIHR made significant investments in students, staff, and facilities and equipment in fiscal year 2010, as it does every year, to ensure the institute's growth and its continuing role as a leading hydroscience laboratory.

Fiscal Year 2000 to 2010 Funding



Fiscal Year 2010 Funding by Sponsor



IIHR Internal Investments in Fiscal Year 2010

Graduate Students	$380,554
Postdoctoral Associates	$80,257
Research Engineers	$440,239
Facilities & Equipment	$931,764
TOTAL	**$1,832,814**

Major Funding News Announced in Fiscal Year 2010

- **Iowa Floodplain Mapping Project**
  $10,000,000: State of Iowa
  Nathan Young, Witold Krajewski, Larry Weber
- **Iowa Flood Center**
  $1,300,000 for year two operations: State of Iowa
  Witold Krajewski, Larry Weber
- **Fish Passage**
  $15,000,000: Public Utility District #2 of Grant County
  Larry Weber, Troy Lyons, Marcela Politano, and Justin Garvin
- **Multiscale Interaction of Pulmonary Gas Flow and Lung Tissue Mechanics**
  $1,400,000: National Institutes of Health
  Ching-Long Lin
- **Local Flow Measurement System for Wave Basin**
  $928,000: Office of Naval Research
  Fred Stern and Joe Longo
- **6DOF Unsteady Viscous Ship Hydrodynamics**
  $2,800,000: Office of Naval Research
  Fred Stern
- **Semi-Volatile PCBs: Sources, Exposures, Toxicities (Iowa Superfund Basic Research Program)**
  $918,886: National Institutes of Environmental Health Sciences (NIH)
  Keri Hornbuckle, Jerald Schnoor, and Craig Just

  Additional funds expected in each of the next four years

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Director of Development and Communication
IIHR—Hydroscience & Engineering
The University of Iowa
Iowa City, Iowa

PHOTO BY MIKE STENERSON/UI CMP—PHOTO SERVICES

IIHR Advisory Board, October 2010: (front, l to r) Pedro J. Restrepo, Teresa J. Newton, Carmen Langel, and Eric Paterson; (back, l to r) Larry Weber, Patrick L. Brezonik, John Engel, and James Smith.

The University of Iowa
100 C. Maxwell Stanley Hydraulics Laboratory
Iowa City, Iowa 52242-1585

IIHR—Hydroscience & Engineering
The University of Iowa
319-335-5237

www.iihr.uiowa.edu

The University of Iowa
College of Engineering